Wind energy conversion in the built environment

Wind turbines at buildings
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Besides their interest in solar energy, architects and project developers tend to have a growing interest in the application of wind turbines at buildings. From them a demand for knowledge on the subject is put forward and this is one of the reasons for research on wind energy conversion in the built environment at the Delft University of Technology. This abstract describes some of the important phenomena and conclusions concerning wind turbines at buildings, which is a part of the research on wind energy conversion in the built environment [1].

It seems a legitimate question: "why not produce wind power where it is consumed": the built environment and avoid transport costs? In addition to this advantage the reimbursement is high because the produced energy can be fed directly into the grid of the building. This causes a reduction of the external energy demand of the building, which is thus reimbursed with the customer price of the utility. But wind energy conversion in the built environment does have disadvantages. Wind speed in the built environment is only a fraction of the wind speed in rural areas, so one has to move to higher locations to reach the higher wind speeds. Siting wind turbines on roofs of (higher) buildings seems an obvious solution, the more because the building causes the local undisturbed wind speed well above the roof to increase some 20% (Figure 1) dependant on the wind direction and the building orientation. This direction dependant change in wind speed causes the Weibull distribution of the wind in the built environment to change to the much wider Weibull distribution well above the roof (Figure 2).

Most buildings can be characterized aerodynamically as bluff bodies. The flow is determined by early separation at the windward roof edge. As a consequence, the increased wind speed above the separation bubble on the roof is not horizontal (Figure 3). Wind turbines at the roof operate in skewed flow. Horizontal axis wind turbines produce less power when operated in skewed flow[1]. For an H-Darrieus rotor this is not necessarily the case. They can even produce more power in skewed flow. The reason is found in an increased rotor area experienced in skewed flow because of the three-dimensional shape of the H-Darrieus rotor. Measurements (Figure 4) and theoretical models [2] support the presence of a power increase of the H-Darrieus rotor in skewed flow. Furthermore the H-Darrieus rotor is more suitable for frequent and rapid changes in wind direction since this does not influence its performance. A horizontal axis wind turbine with its yaw mechanism is not able to follow rapid changes in wind direction. The H-Darrieus rotor thus seems favorable for operation at buildings and, because of the increase in power output in skewed flow, even more favorable for operation at roofs.

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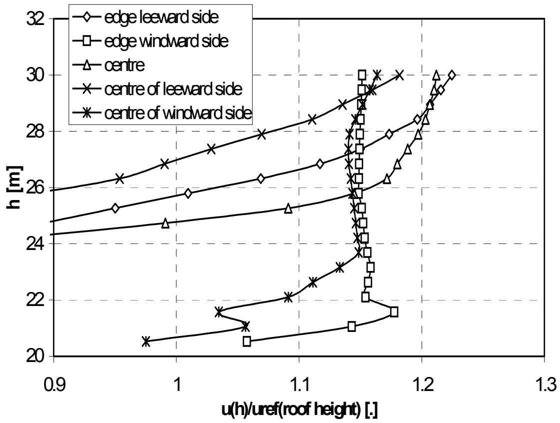
[1] Normally this condition is called yawed operation but for our purpose we define it as skewed to distinguish between the horizontal plane for yawed and the vertical plane for skewed flow.



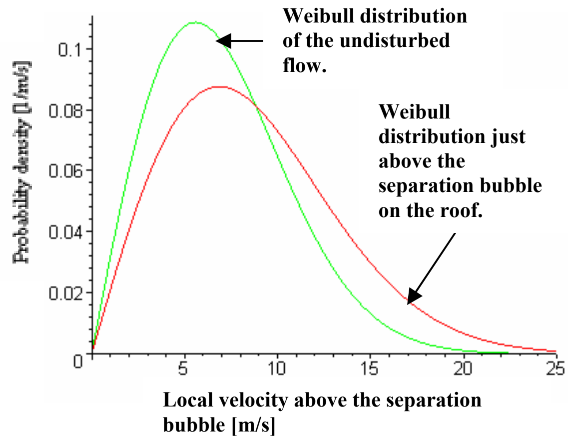
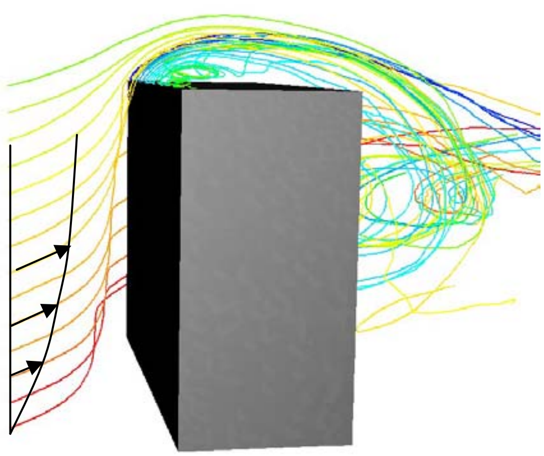


Figure 1. CFD calculation of the wind speed above the roof *u* (roof height 20 m) at height h compared to the undisturbed wind speed at roof height *uref(roof height)*. The flow direction is taken perpendicular to the long side of the building

Figure 2. Example of the change in Weibull distribution caused by the direction dependant increase of the undisturbed wind speed.



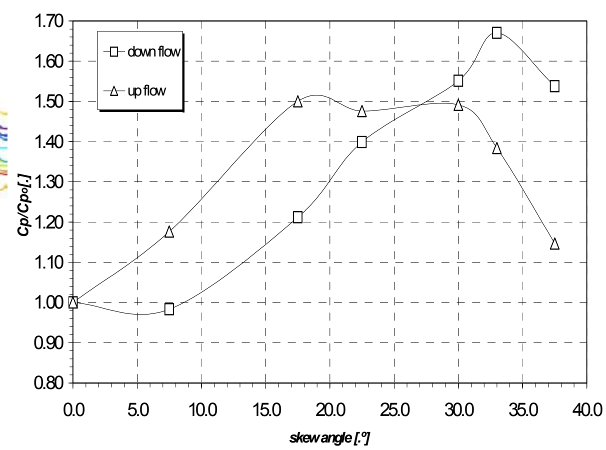


Figure 3. CFD calculation of the streamlines in boundary layer flow. The flow direction has an angle of 45 degrees towards the long side of the building. Early separation at the windward roof edge that causes a separation bubble at the roof is clearly visible.

Figure 4. Measured change in power coefficient $C_P / C_{P,0}$ of an H-Darrieus with skewed blades (see www.turby.nl) in skewed flow with skew angle γ, where C_P is defined on the frontal area and $C_{P,0}$ is taken as the power coefficient with normal flow $\gamma = 0$.

References:

[1] Mertens, S., Wind energy in urban areas, concentrator effects for wind turbines close to buildings, Refocus, March/ April 2002

[2] 22nd ASME wind energy conference in Reno, Aerodynamic efficiency of wind turbines in Skewed flow on a roof, Jan 2003